MEMS Track Monitoring System

97806599

This equipment should be installed, maintained, and operated by technically qualified personnel. Any errors or omissions in data, or the interpretation of data, are not the responsibility of Durham Geo Slope Indicator Company. The information herein is subject to change without notification.

SLOPE INDICATOR
12123 Harbour Reach Drive
Mukilteo, Washington, USA, 98275
Tel: 425-493-6200 Fax: 425-493-6250
E-mail: solutions@slope.com
Website: www.slopeindicator.com

Contents

Introduction

Disclaimer

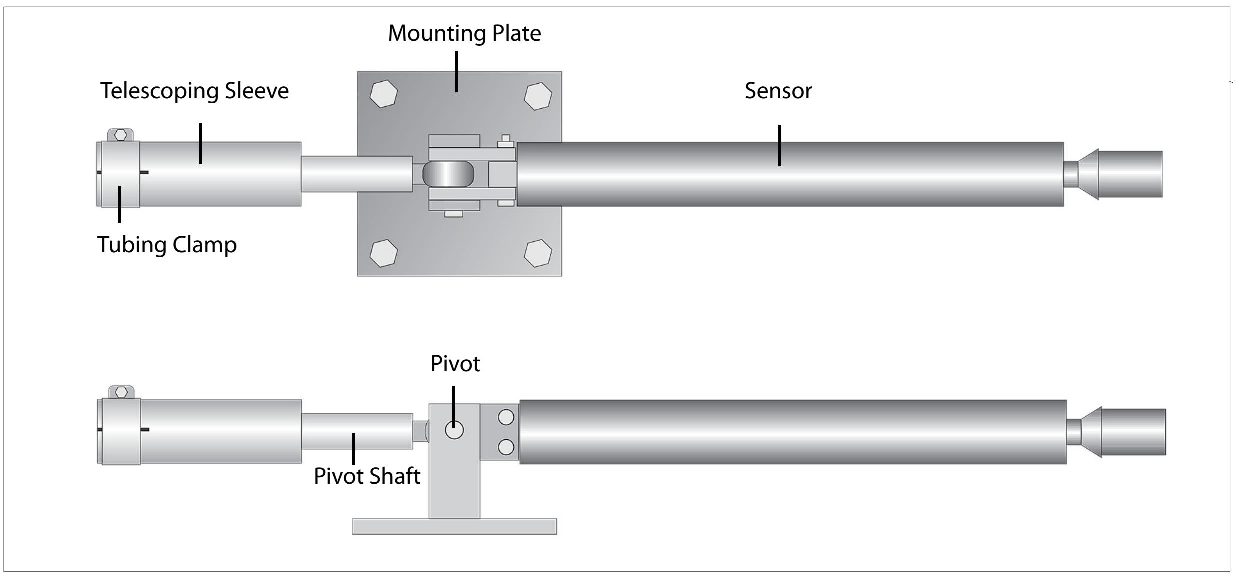
This manual assumes that the railroad engineer has established the requirements for monitoring, the number and placement of the sensors, and acceptable methods for installing the sensors. The instructions provided in this manual are intended to provide some guidance and do not replace the advice of the railroad engineer.

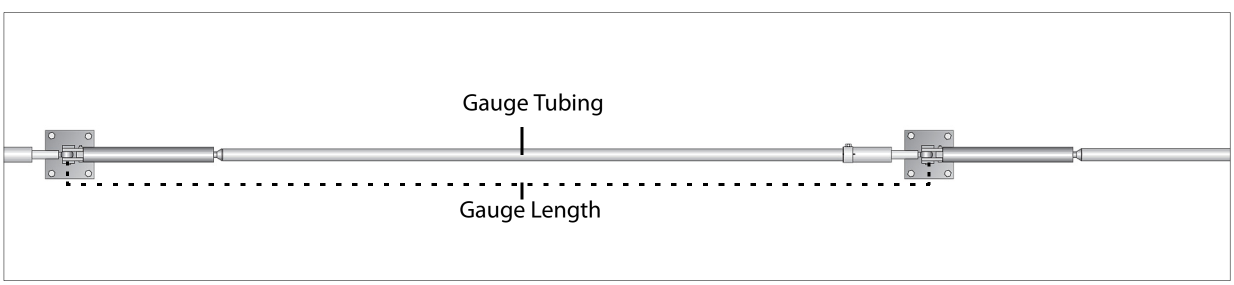
Overview

Track monitoring systems can help maintain the safety of railroad tracks by monitoring settlement and twist. The systems are installed on tracks that may be affected by nearby tunneling or excavation. They are also installed on tracks that cross potential washout and landslide areas.

Settlement Sensor

Settlement sensors are installed parallel to the rails. Components of the sensor are identified below.



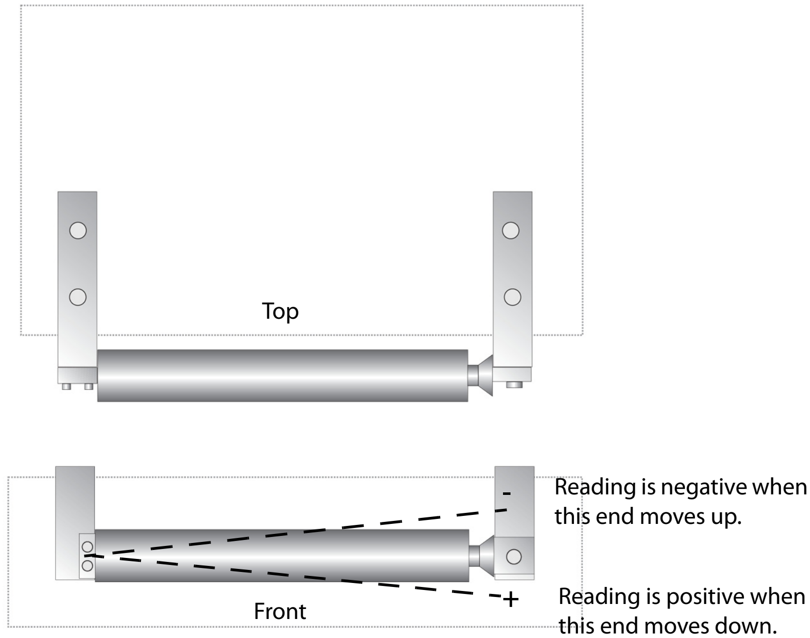


Gauge tubing completes the sensor gauge length.

The actual gauge length of the sensor is the distance between pivots.

Twist Sensor

Twist sensors are mounted parallel to the ties (perpendicular to the rails). They can be connected (electrically) in line with settlement sensors. The "gauge length" is the distance between mounting brackets: 305mm (12 inches).

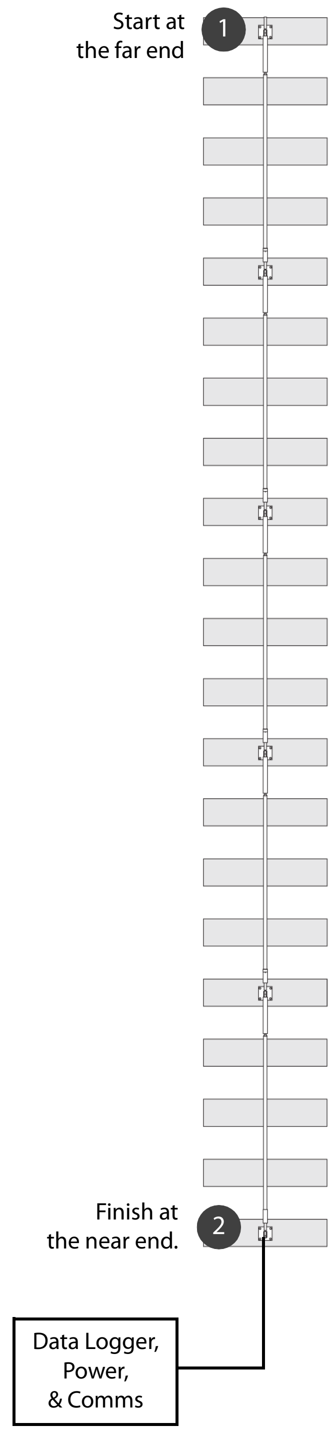


Planning

Sequence for Installation

Determine the end points of the chain of sensors and the location of the logger. Then . . .

1. Start installing sensors at the far end (the end of the chain that is farthest from the logger).
2. Finish at the near end (the end of the chain that is nearest to the logger).



Sensor Placement

Factors affecting sensor placement:

Tie Spacing: Sensors are mounted on ties, so the spacing of the ties determines placement.

Signal Cable: Each sensor is supplied with cable to permit gauge lengths of 10 feet or 3 meters (adjusted to the nearest tie).

Required Precision: Shorter gauge lengths provide higher precision.

Stable Origin: Ideally, one end of the chain of sensors is located on stable ground.

Logger Placement

Factors affecting logger placement:

Protection: The logger is typically placed in a protected location, such as a signals shack or in an enclosure mounted high on a pole.

Communications: The logger should be placed to allow reliable transmissions for point to point radios, good signal strength for cellular modems, etc.

Power: The logger must be placed near power sources and solar panel, if used.

Serial Numbers

Each sensor has a serial number and a matching calibration record.

- Keep the calibration records in a safe place.
- Use the installation report to record sensor serial number, position, type (settlement or twist), etc.

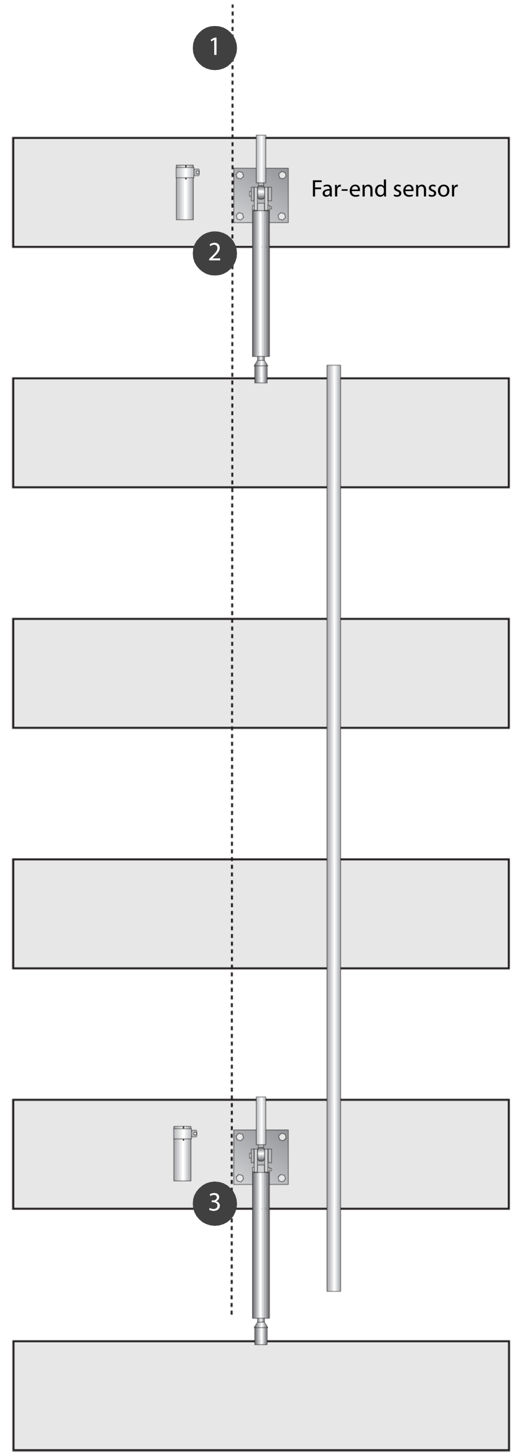
Installing Sensors

Install the Far-End Sensor

These installation drawings show the process of installation, starting at the far end of the chain and working toward the data logger.

The drawings are not to scale and do not represent the actual spacing of ties and sensors, or any other details at a real site.

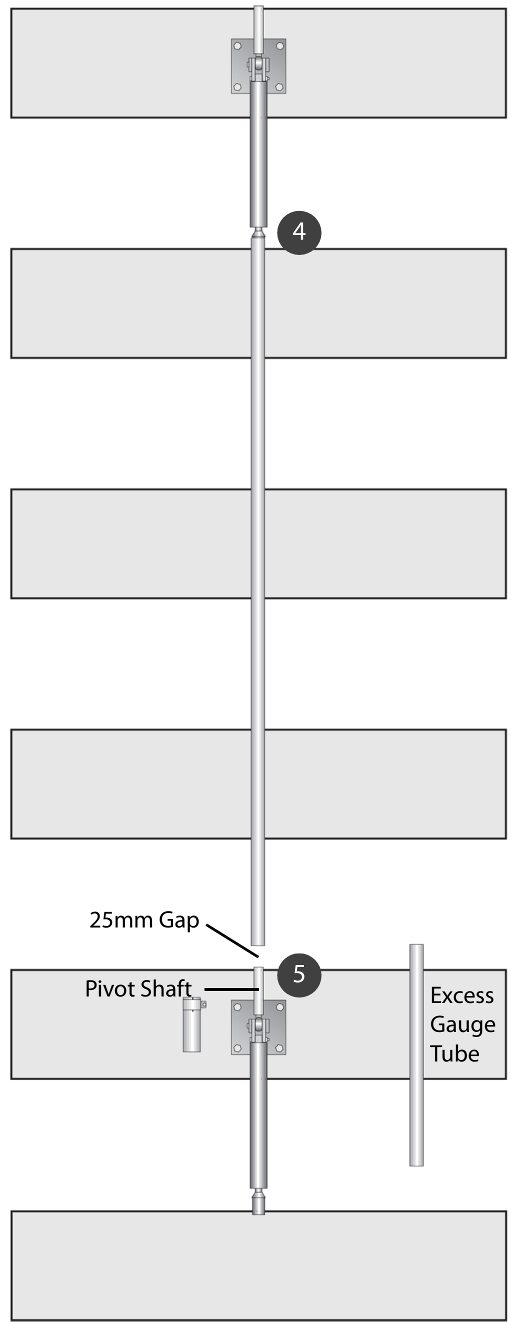
1. Mark ties to show sensor locations and alignment of the system.
2. Place the far-end sensor and fasten it to the tie. Remove the telescoping sleeve. It is not used.
3. Place the next sensor and fasten it to the tie. Keep the telescoping sleeve for later.



Measure & Cut Gauge Tube

4. Temporarily fit the gauge tube onto the sensor.

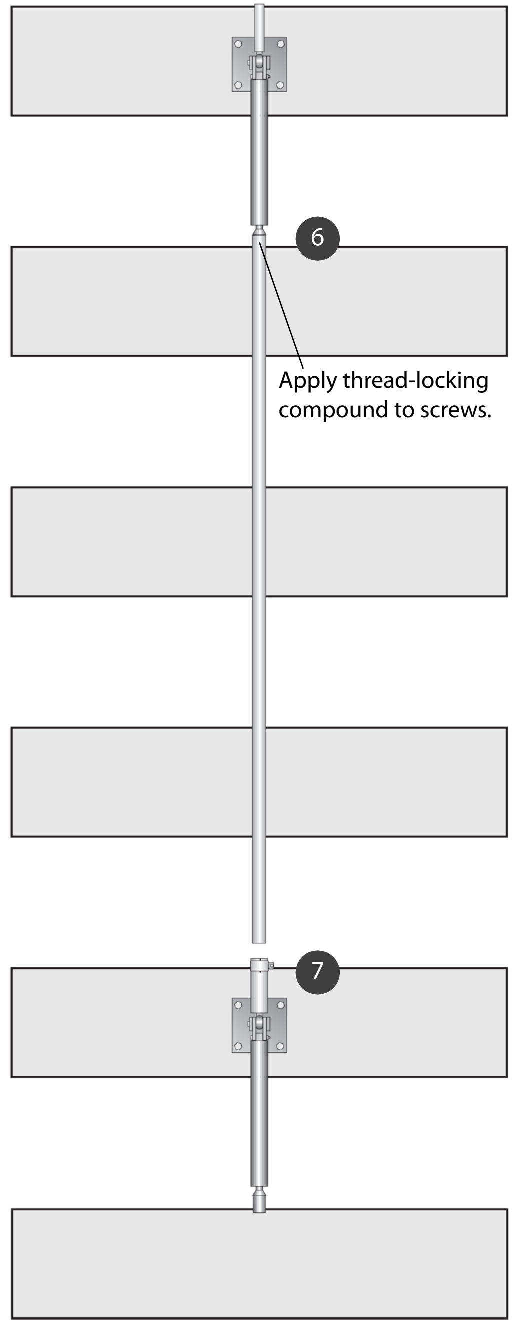
5. Determine the proper length for the gauge tube: Allow a 25 mm (1 inch) gap between the end of the gauge tube and the pivot shaft. Cut off the excess tube length.



Join the two Sensors

6. Secure the gauge tube to the sensor with screws. Apply thread-locking compound to prevent screws from vibrating loose.

7. Slip the telescoping sleeve onto the pivot shaft.



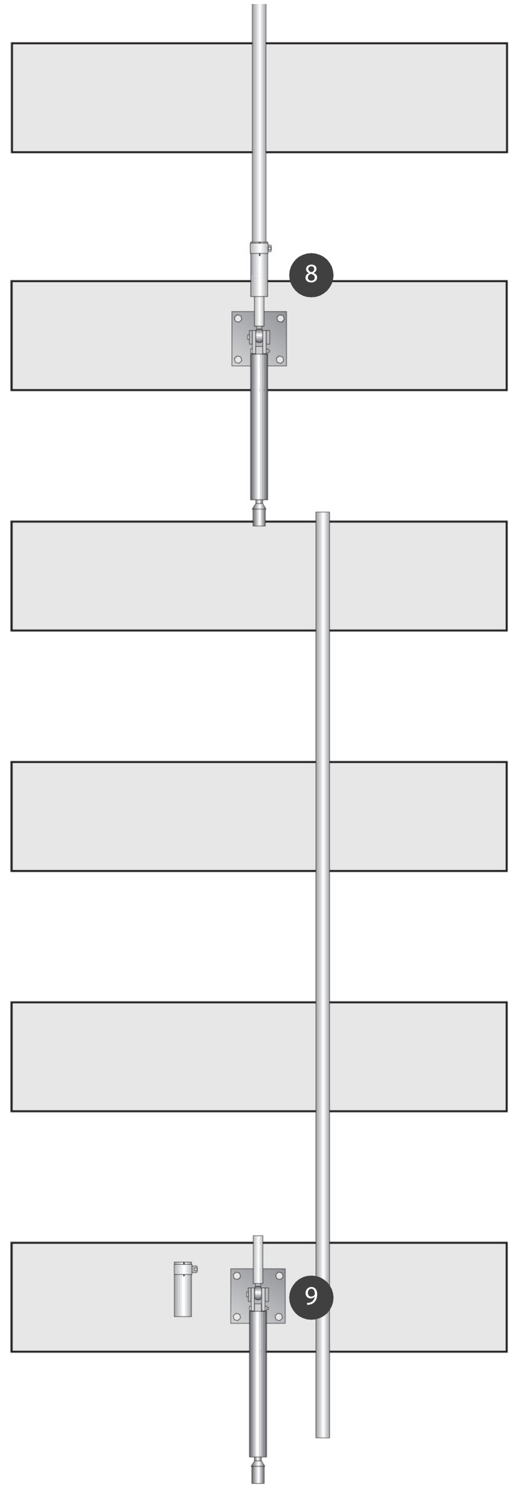
Install the next sensor

8. Slip telescoping sleeve onto gauge tube and tighten the tubing clamp.

9. Place the next sensor and fasten it to the tie. Fit the gauge tube and attach it, using thread-locking compound on the screws. Then tighten the clamp on the telescoping sleeve.

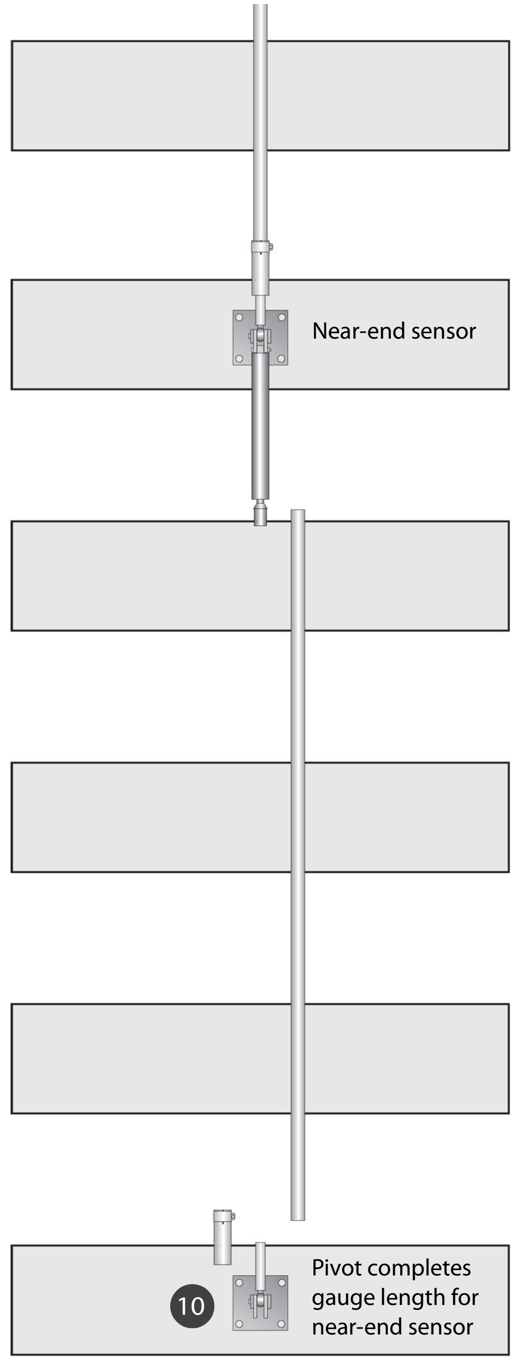
   Repeat steps 3 through 9 until you have installed all of the sensors.

   Note that twist sensors can be installed between settlement sensors.



Complete the Near-End Sensor

10. Complete the gauge length of the near end sensor. Fit the gauge tube between the sensor and the final pivot and tighten the clamp on the telescoping sleeve.

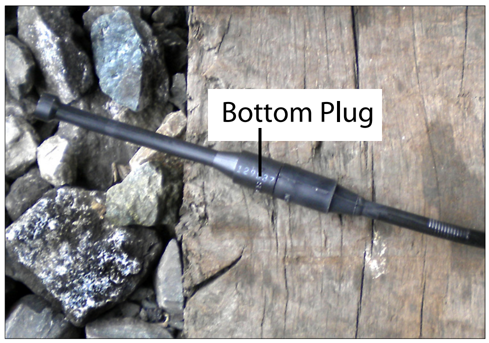


Connecting Cables

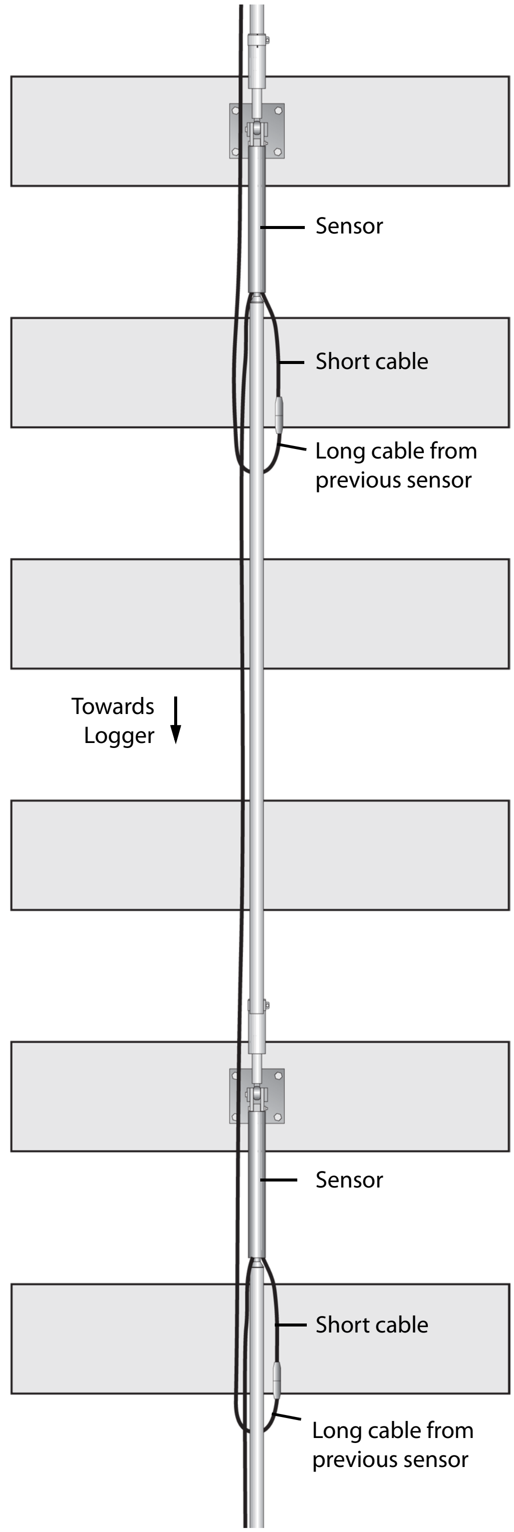
Connect Signal Cables

Each sensor has a short cable and a long cable. The short cable receives the long cable from previous sensor. The long cable runs to the next sensor.

- Use a bottom plug to terminate the short cable on the far-end sensor.



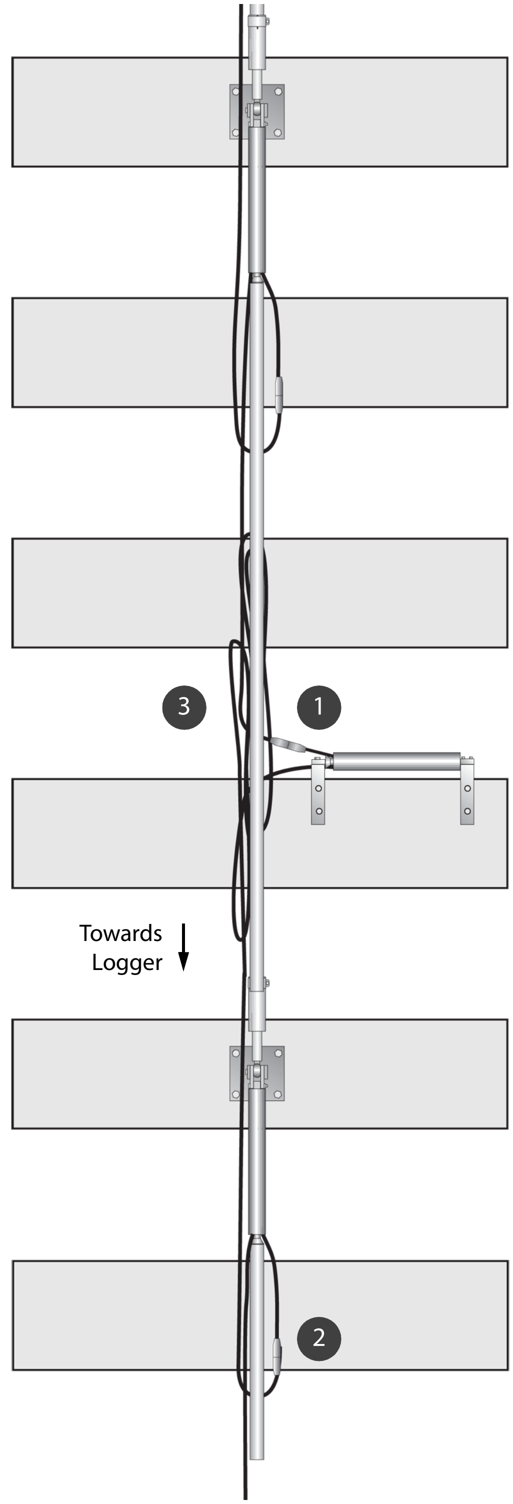
- Use a jumper cable (not shown) to connect the near-end sensor to the logger.
- Secure all cables well, using cable ties and straps.



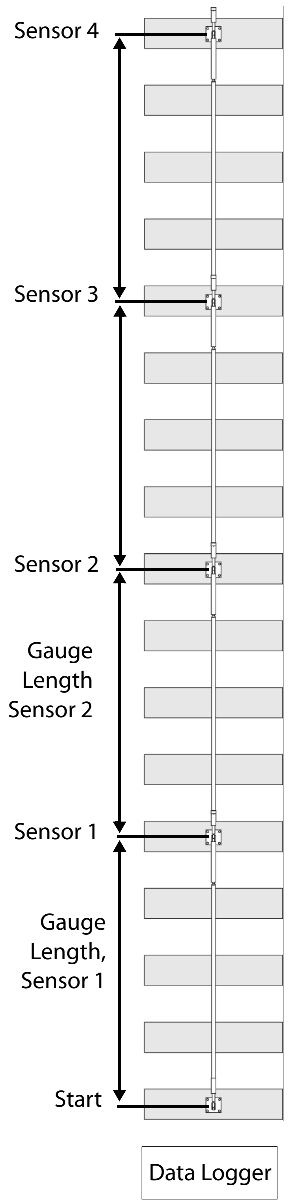
Connecting Twist Sensor In-Line

Twist sensors can be connected in-line with settlement sensors. In the drawing at right, the twist sensor is mounted mid-way between two settlement sensors.

1. Connect the long cable from the previous settlement sensor to the short cable of the twist sensor.
2. Then, connect the long cable from the twist sensor to the short cable of the next settlement sensor.
3. Coil excess cable (in a single layer), then secure all cables with cable ties and straps.



Installation Report



This information is required for data processing. Sensor 1 is the near-end sensor. Sensor n is the far end sensor. Find the serial number on the sensor body. Gauge length is the distance between pivot points. Measure carefully, since it is likely to be slightly different for each sensor. Elevation and mile/km are railroad data.

Sensor	Serial Number	Type (S or T)	Gauge Length	Elevation	Mile/km
Start	-	-	-		
1					
2					
3					
4					

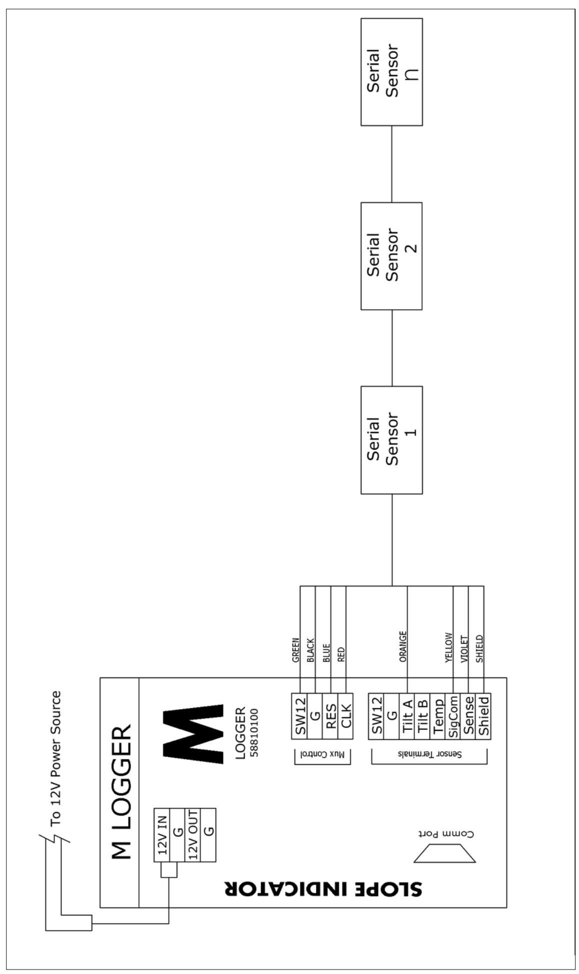
Data Logging

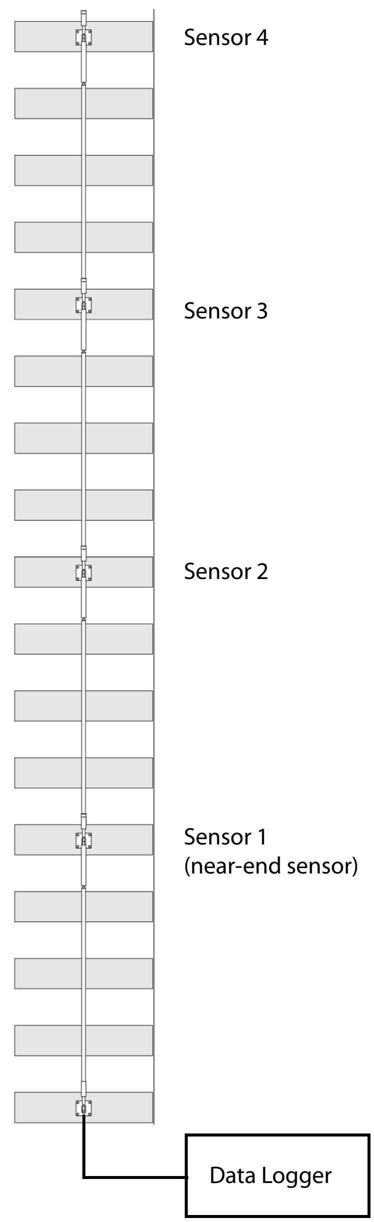
Compatible Loggers

- Compatible loggers include the Campbell Scientific CR1000 or CR800. A sample program and wiring diagram for the Campbell loggers is available from www.slopeindicator.com > Support > Tech Notes > Sample Programs for CR1000. Choose MEMS Serial Sensors, Uniaxial.
- Slope Indicator's M-Logger can read up to 16 serial sensors. A wiring diagram for the M-Logger is provided below. See the M-Logger manual for more details.

Logging Sequence

The logging sequence for both the Campbell Loggers and the M-Logger starts with the near-end sensor, which is labelled sensor 1 in the drawing below





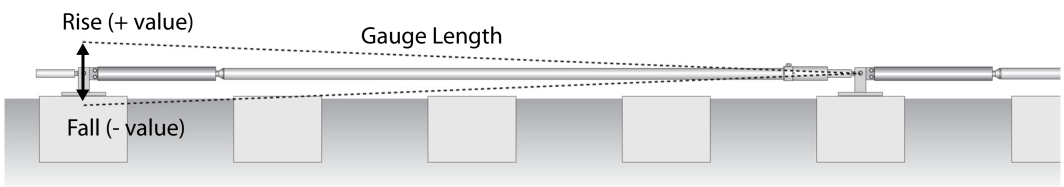
Data Processing

Introduction

Settlement sensors are used to detect and quantify differential settlement along the alignment of the track. The steps below show how tilt measurements from the sensors are processed to provide settlement data.

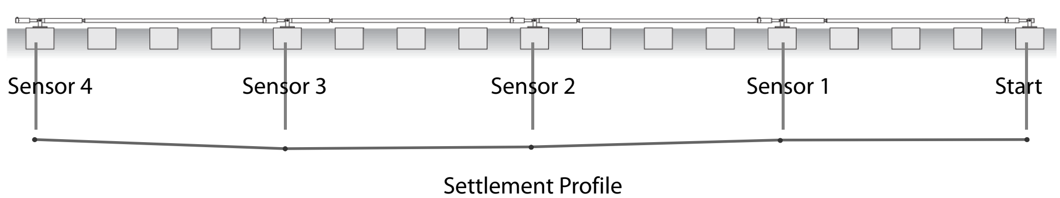
1. Convert voltage readings to tilt values: Track sensors return voltages to the logger. A polynomial expression is used to convert the voltage reading to a tilt value expressed in mm per meter. The sensor calibration record provides the formula and the coefficients. See Appendix 1 for more information.

2. Convert tilt values to a vertical “rise” or “fall” for each sensor. Multiply the tilt value by the gauge length of the sensor. Note that this rise or fall values is relative to the sensor. It does not represent the true rise or fall of the track. The first set of rise/fall values serves as the baseline.



3. Find changes in the rise/fall value for each sensor. To find changes, subtract baseline rise/fall values from the current rise/fall values. A positive change indicates heave. A negative change indicates settlement.

4. Create a profile plot to show differential settlements: Sum settlement values from near end to far end (Sensor 1 to Sensor n) and plot the result.



Calibration Records

A calibration record is provided with each track sensor. Calibrations are unique for each sensor, so use sensor serial numbers to match sensors with their calibrations.

AC9 to AC0: Use these factors to convert a reading in volts to tilt in mm per meter. Vo is the sensor reading in volts. TC is the internal temperature in degrees Centigrade.

Tilt Formula

Use this formula convert the voltage reading from the sensor to a tilt value.

$$\mathbf{Tilt = C9*Vo^3 + C8*Vo^2 + C7*Vo + C6 + C5*Vo^2*TC + C3*TC + C2*TC^2 + C1*TC^3 + C0*Vo*TC^2}$$

Calculating Rise/Fall

Use this formula to calculate the vertical rise or fall over the gauge length of the sensor. A positive value is rise. A negative value is fall.

Rise/Fall in mm = tilt in mm/m x gauge length of sensor in meters

Calculating Settlement

Settlement or heave is the change in rise or fall. Use the formula below

Settlement or Heave = $\text{rise/fall}_{\text{current}} - \text{rise/fall}_{\text{baseline}}$